MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Absolute Measurements of Light Focused by a Reflector into its Focal Plane

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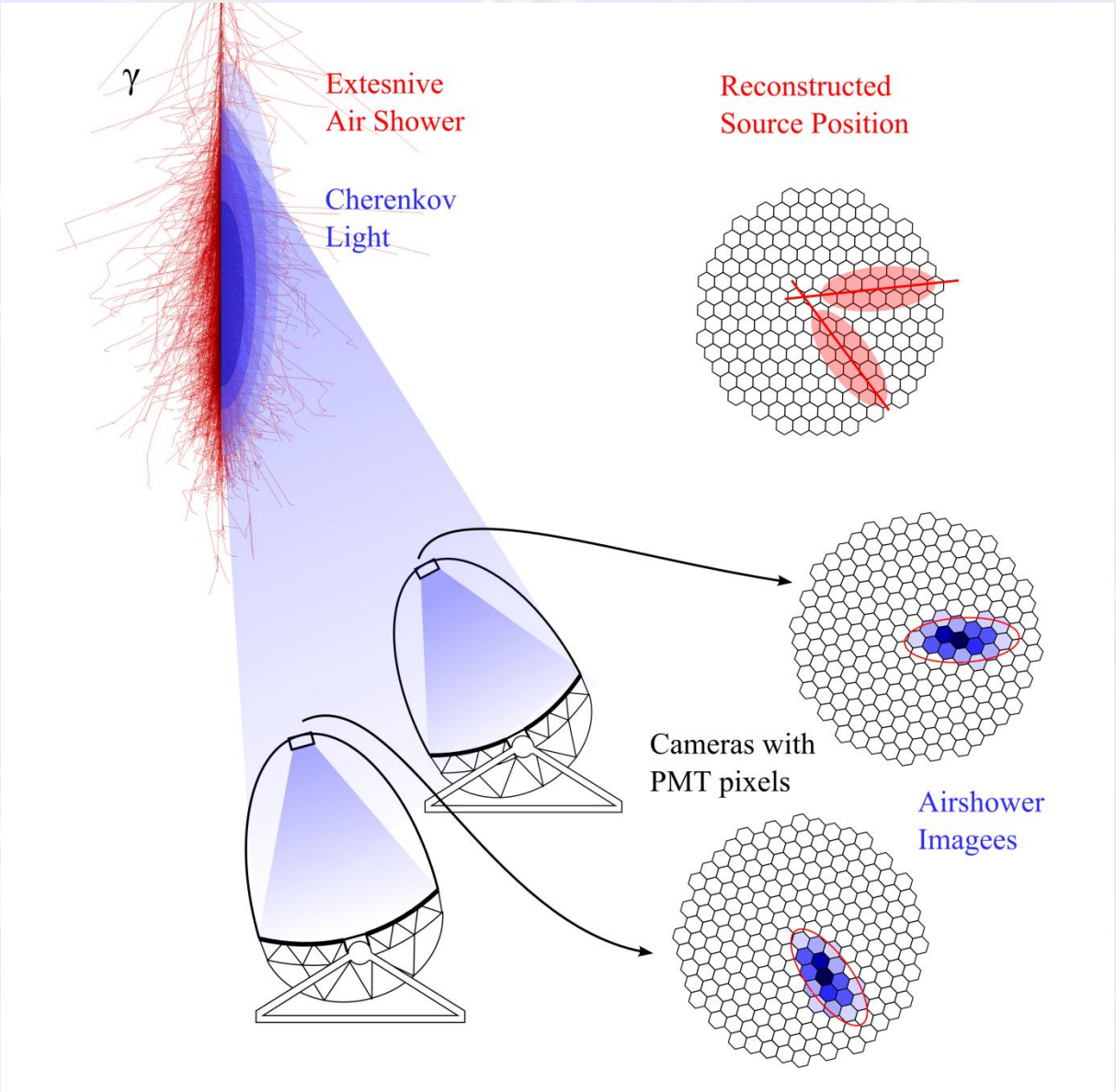
The MAGIC - Project

Major **A**tmospheric **G**amma-ray **I**maging **C**herenkov - **Telescopes**

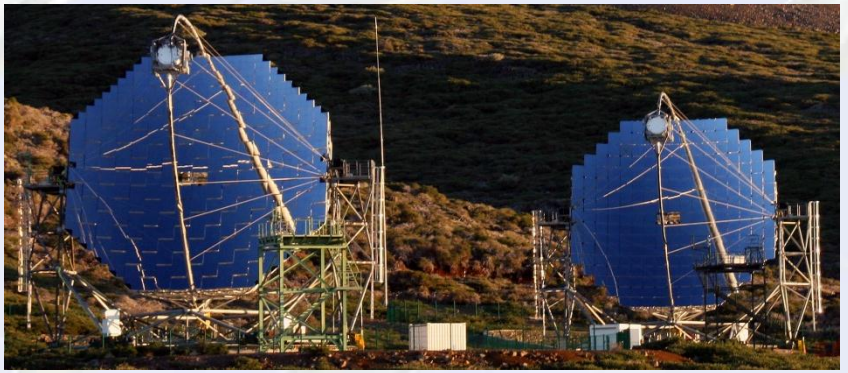
- **World-largest imaging atmospheric Cherenkov telescopes (IACT)**
- **indirect observation method to detect VHE-γ rays**
- **detected light not coming directly from astronomical sources**
  → produced inside the atmosphere
- **precise knowledge of the optical properties is important to reconstruct primary energy and to do γ-hadron separation**

Imaging Atmospheric Cherenkov Technique

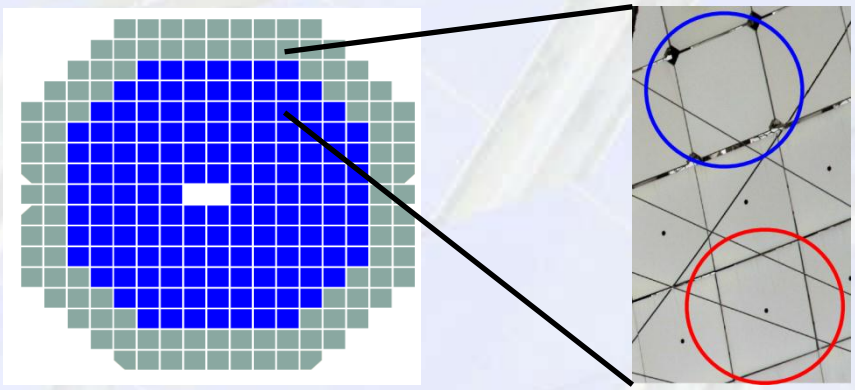


Characterized during my diploma thesis

- reflector of MAGIC I
- reflector of MAGIC II



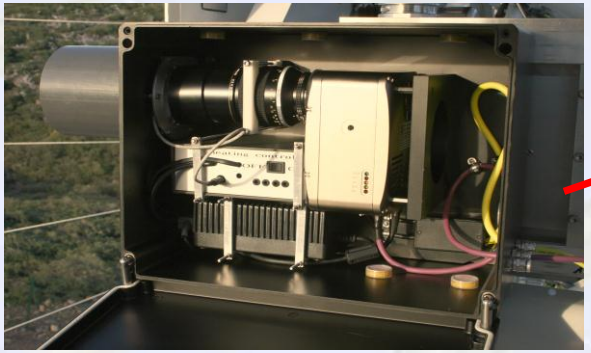
In MAGIC II, two types of mirrors are used: all Al and glass



- difference between aluminum and glass mirrors

Measurement Setup

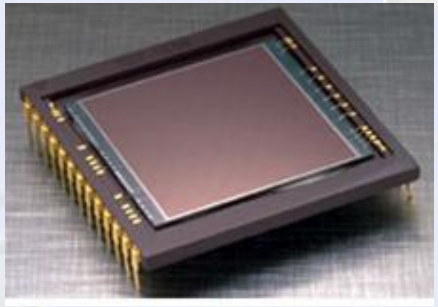
Measurement setup in detail



SBIG camera and optics

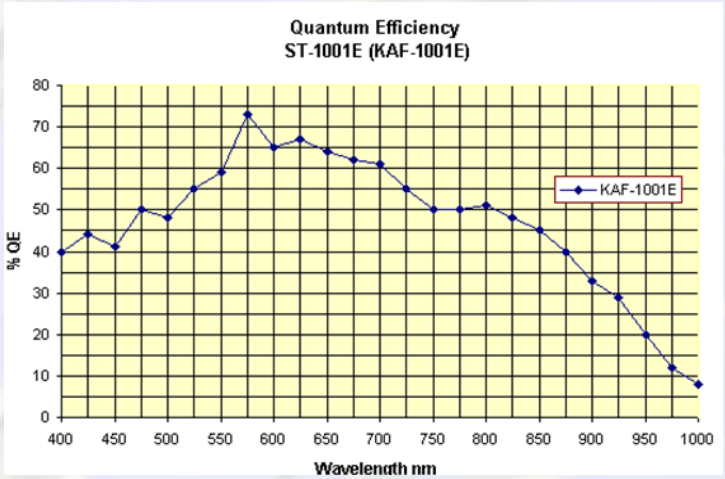
SBIG camera

CCD: **KAF-1001E**
peak QE: **72%**
total pixels: **1.0 million**
array: **1024 x 1024 pixels**
pixel size: **24 x 24 microns**

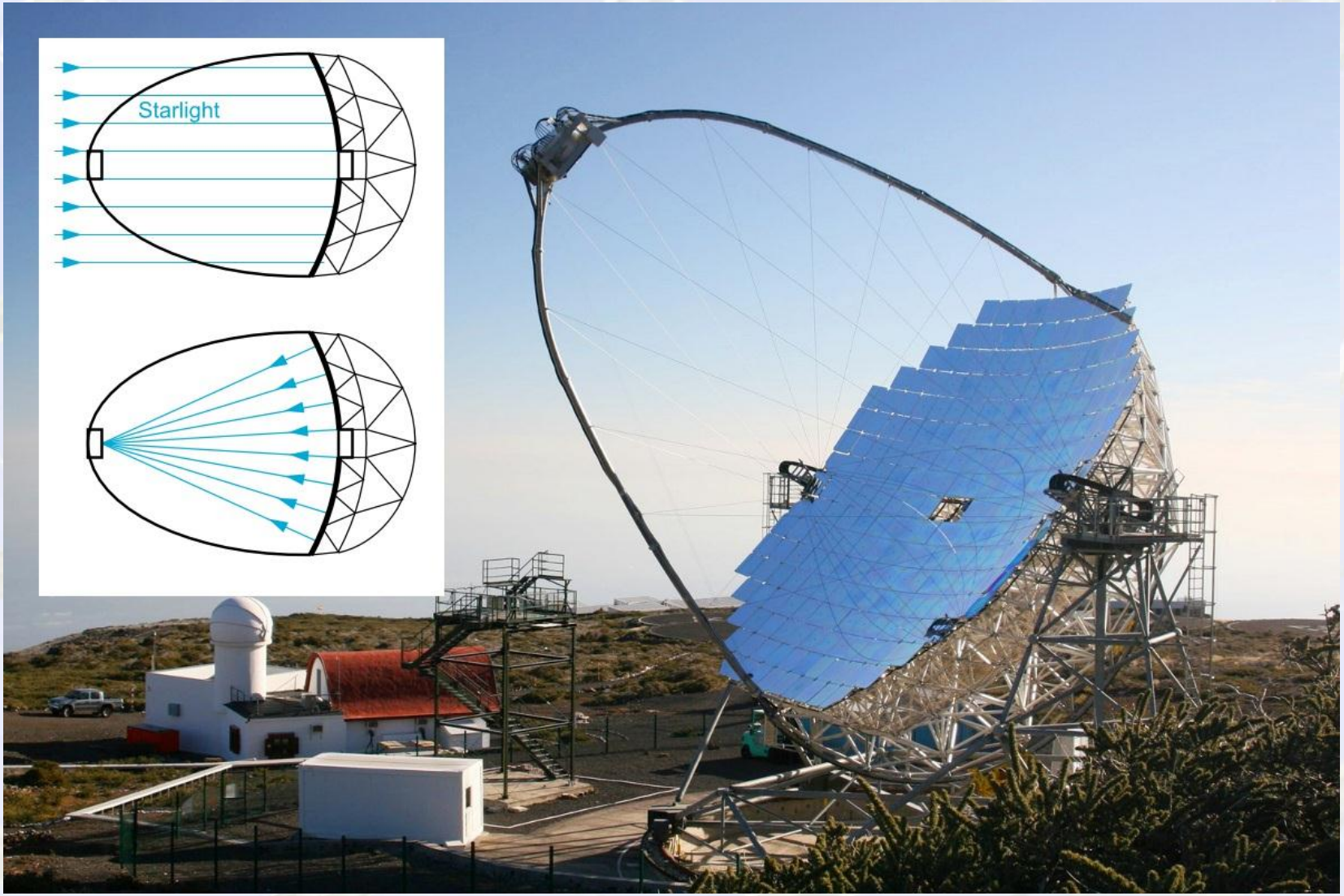


Nikon 108.2

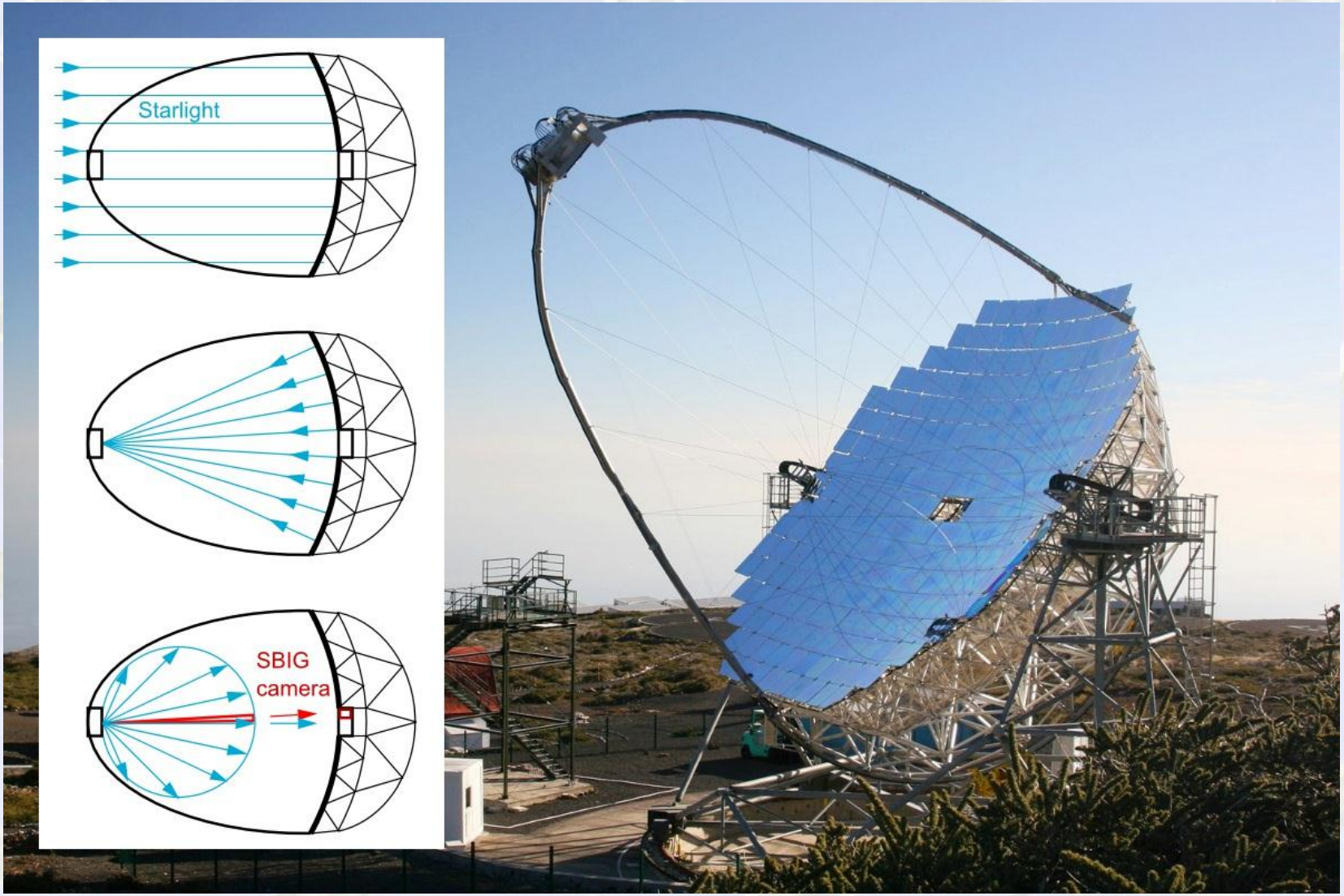
focal length: **180mm**
camera aperture: **F/2.8**



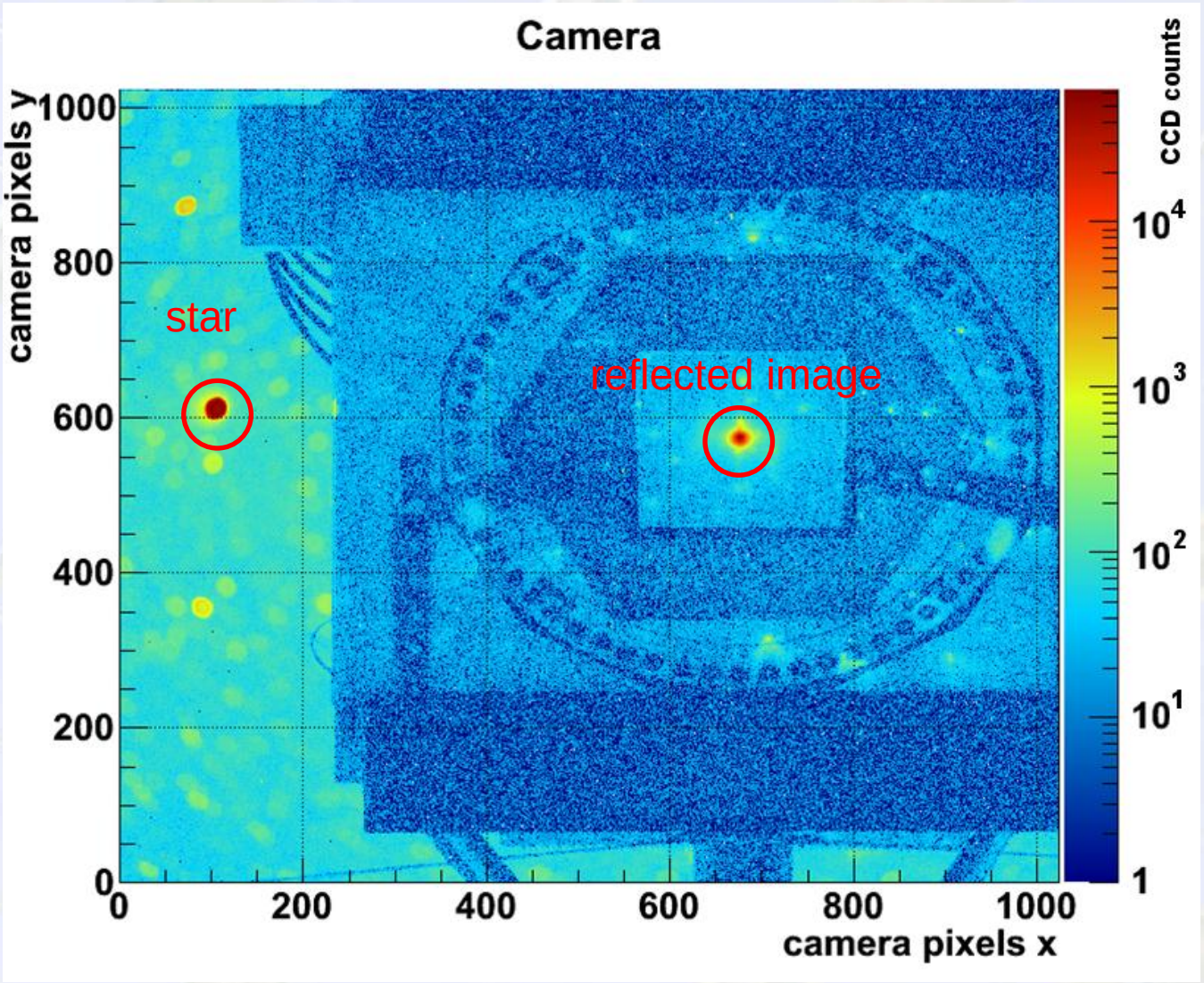
Measurement technique



Measurement technique



Picture taken with the SBIG-Camera



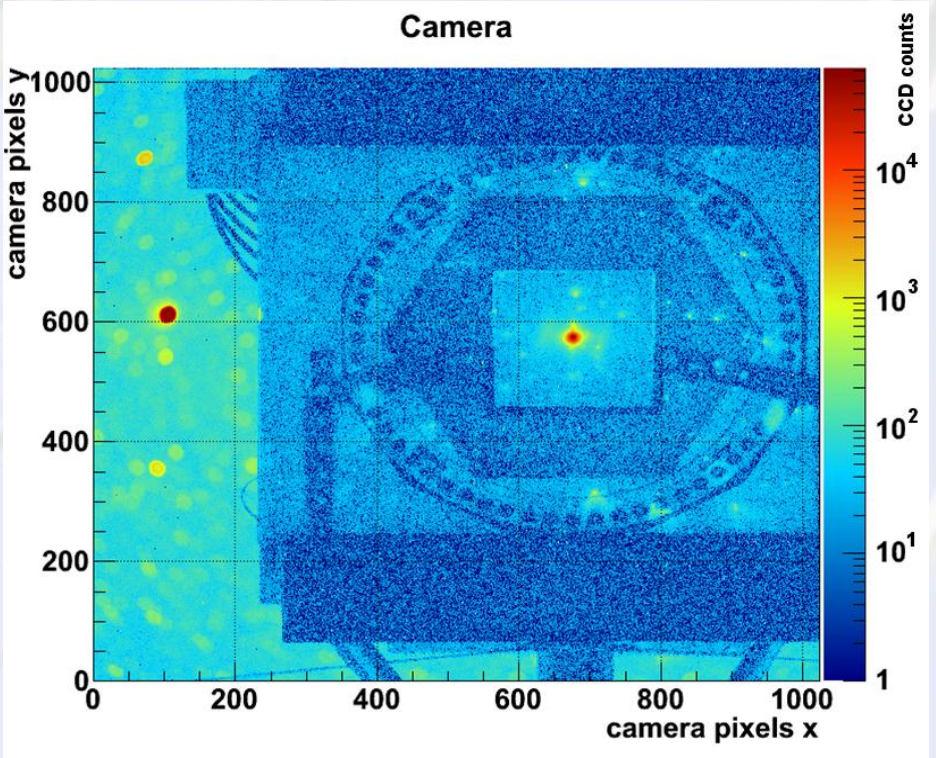
How to calculate the focused reflectivity

$$R_{fok} = \frac{\phi_{indirekt}}{\phi_{direkt}} \cdot C_{geom.}$$

ϕ_{direkt} = sum of counts in the reflection

$\phi_{indirekt}$ = sum of counts in the star

$C_{geom.}$ = geometrical factor

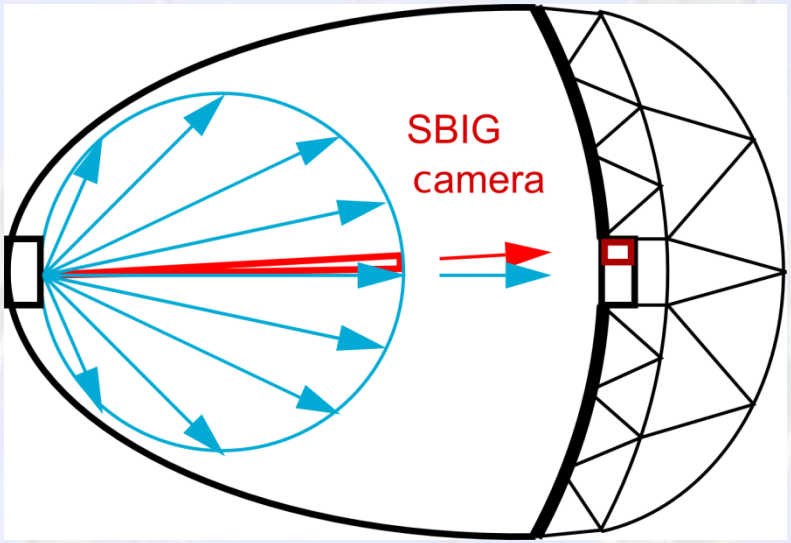


How to calculate the focused reflectivity

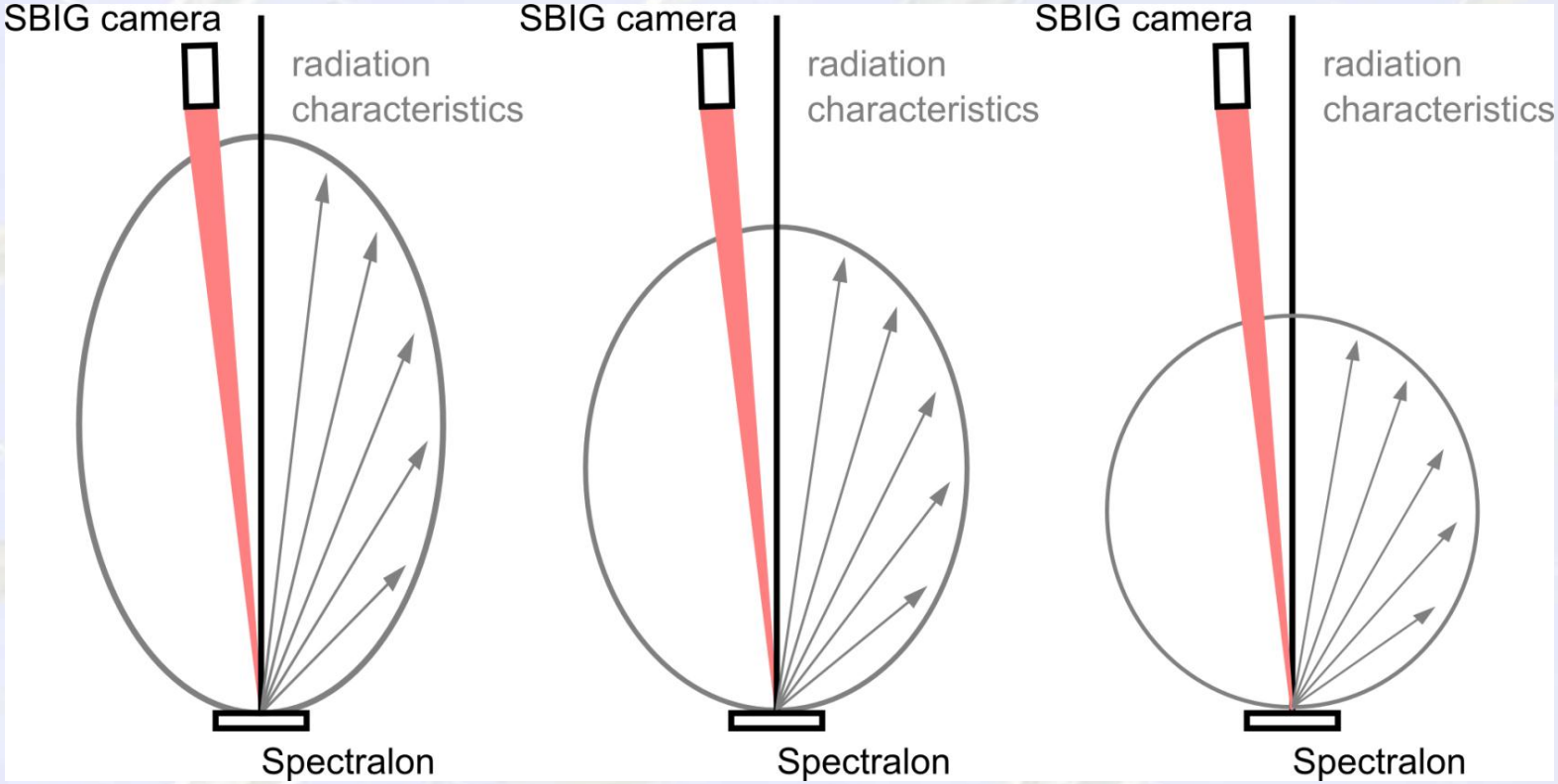
a little bit more detailed…

$$R_{fok} = \frac{\phi_{indirekt}}{\phi_{direkt}} \cdot \frac{r^2}{A_{HSP}} \cdot \frac{\Omega_{eff}}{R_{Sp}} \cdot \frac{1}{\cos(4.24°)^{1.15}}$$

Mirzoyan, et al., 2007



Examples for different radiation characteristics



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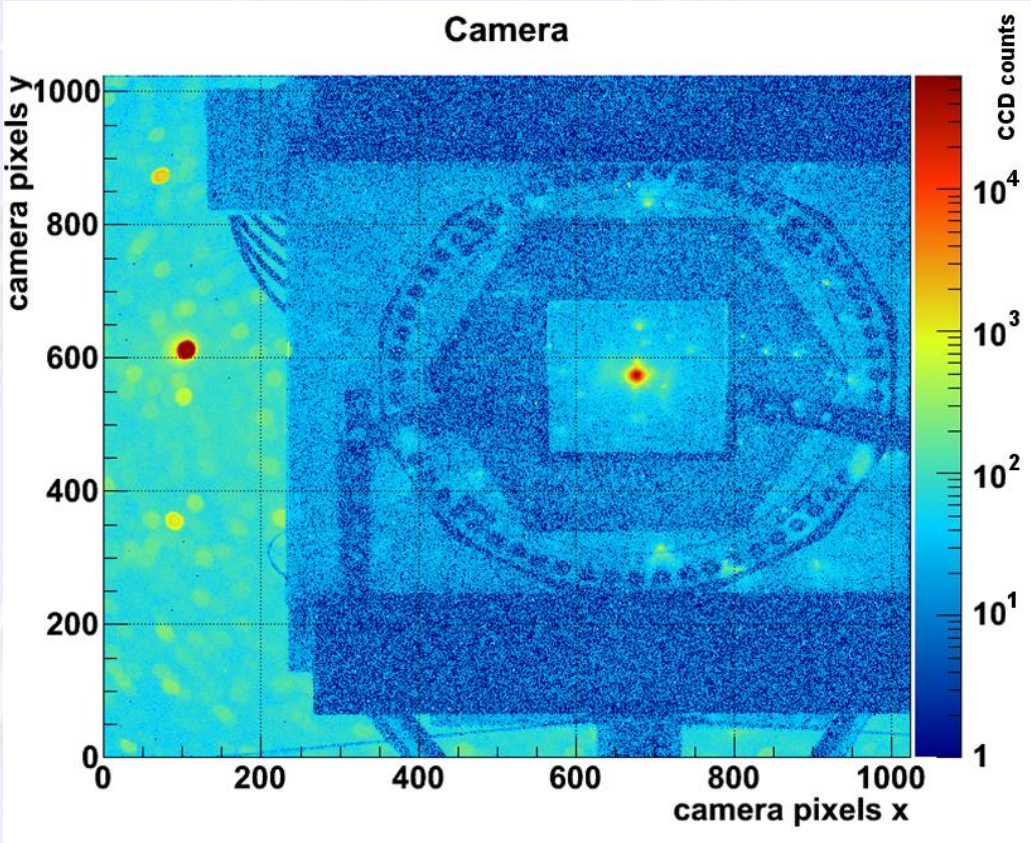
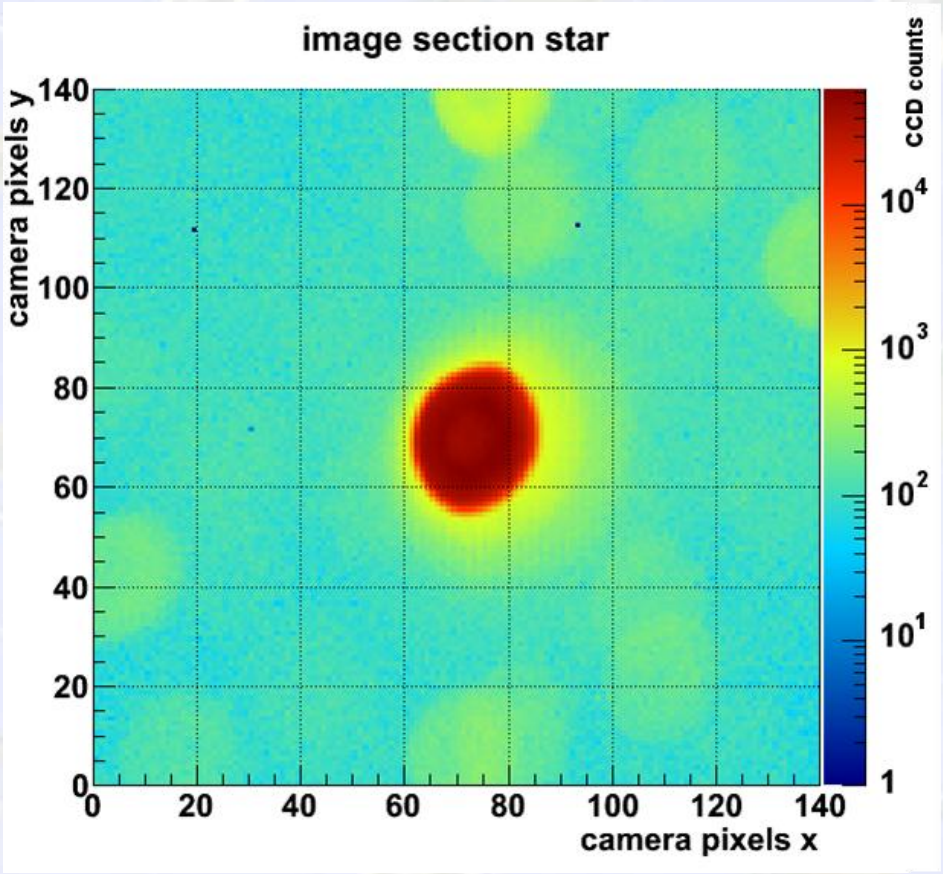
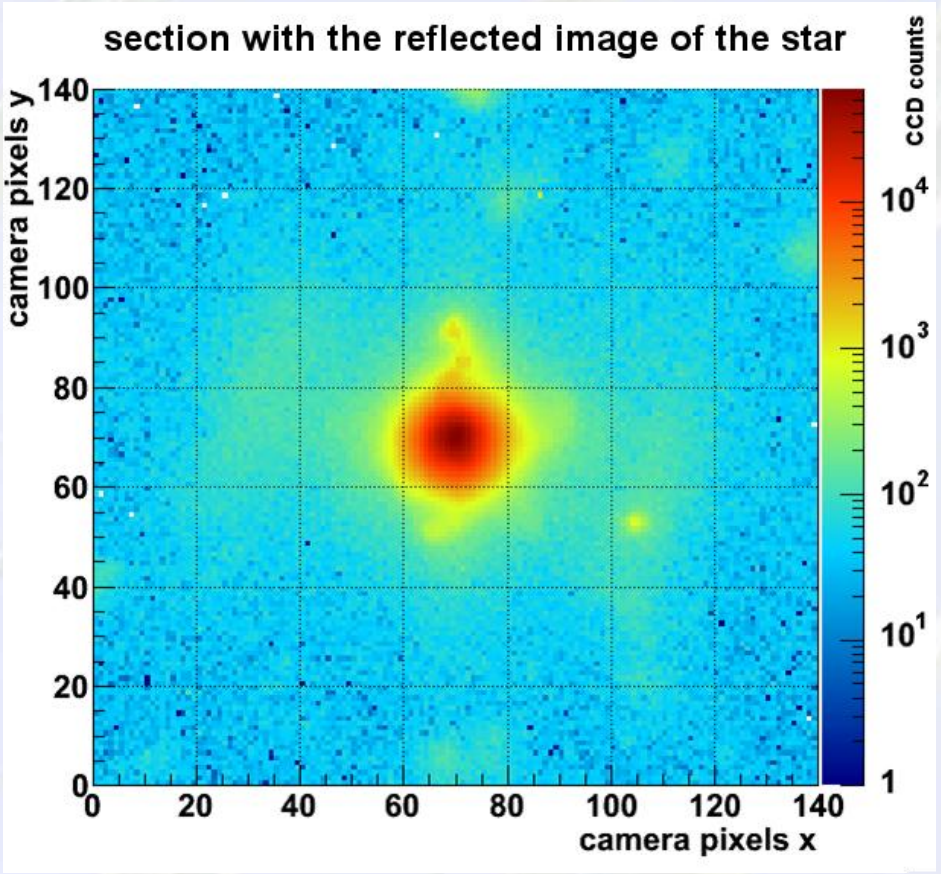
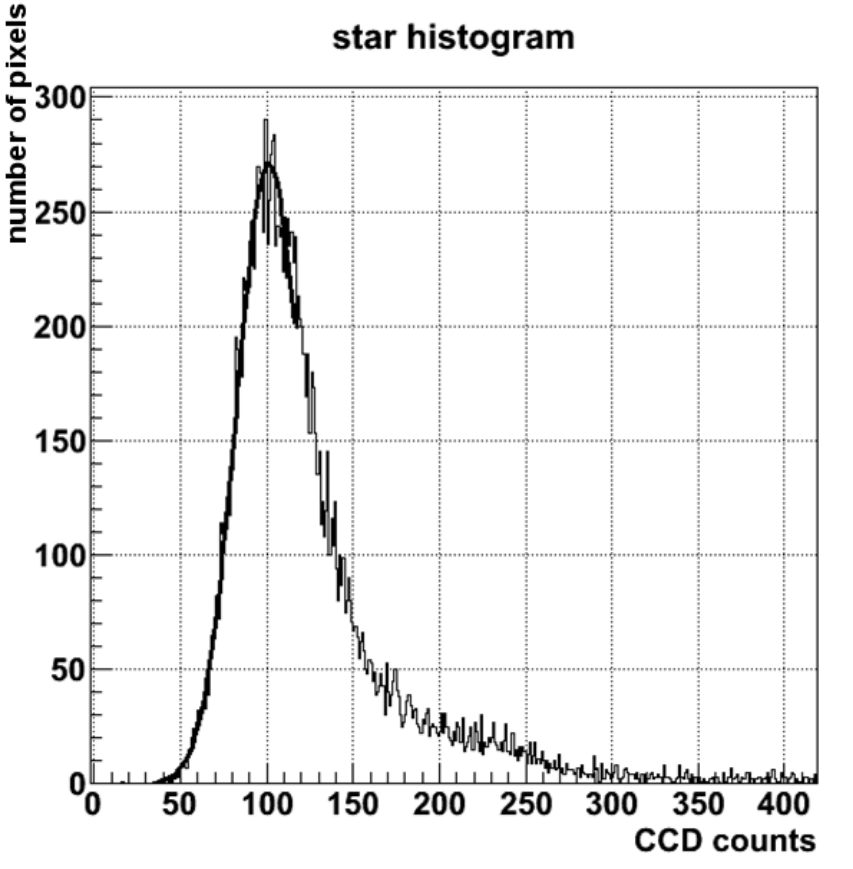


Image sections





Subtracting the background



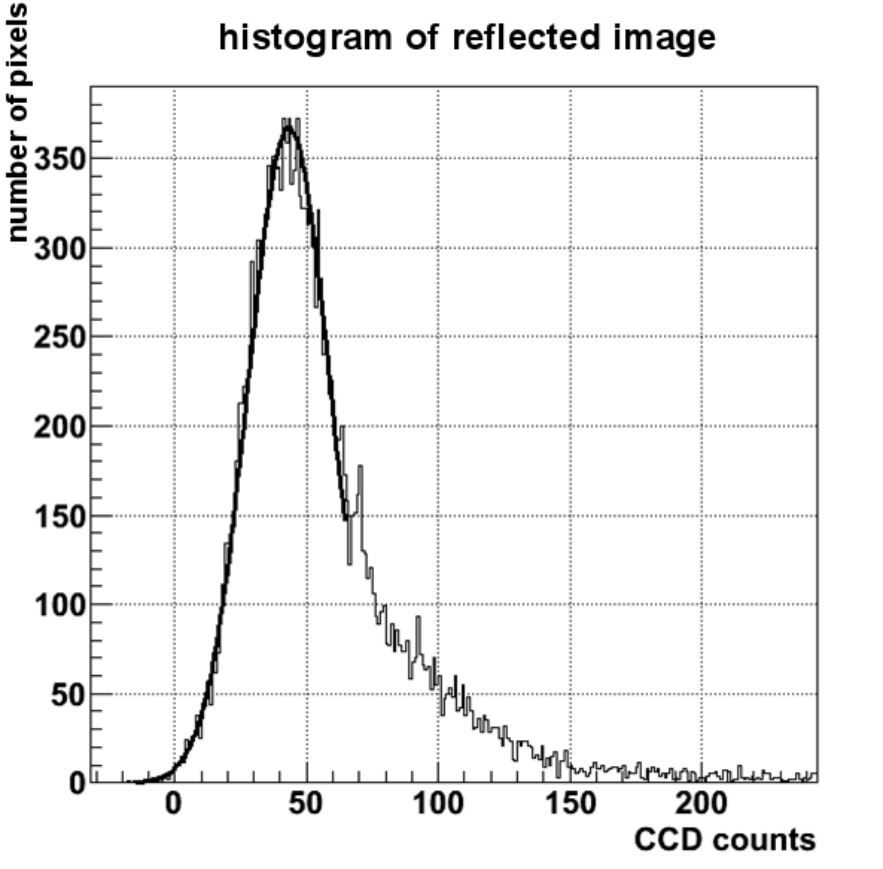
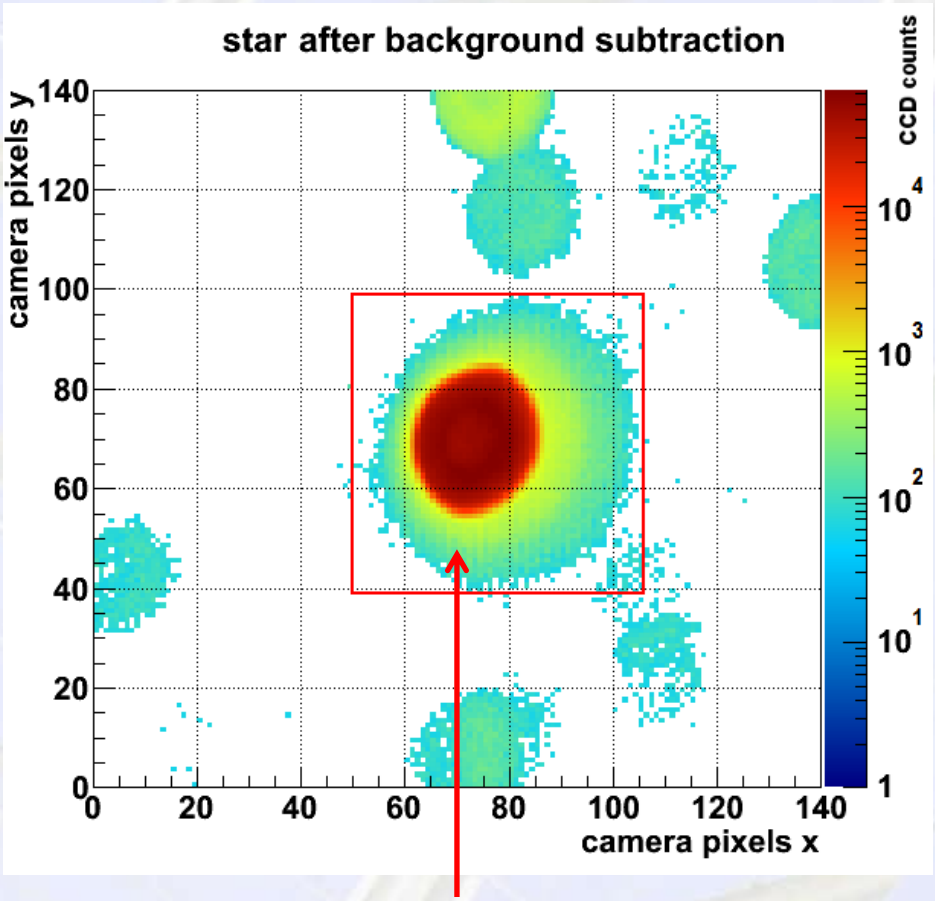
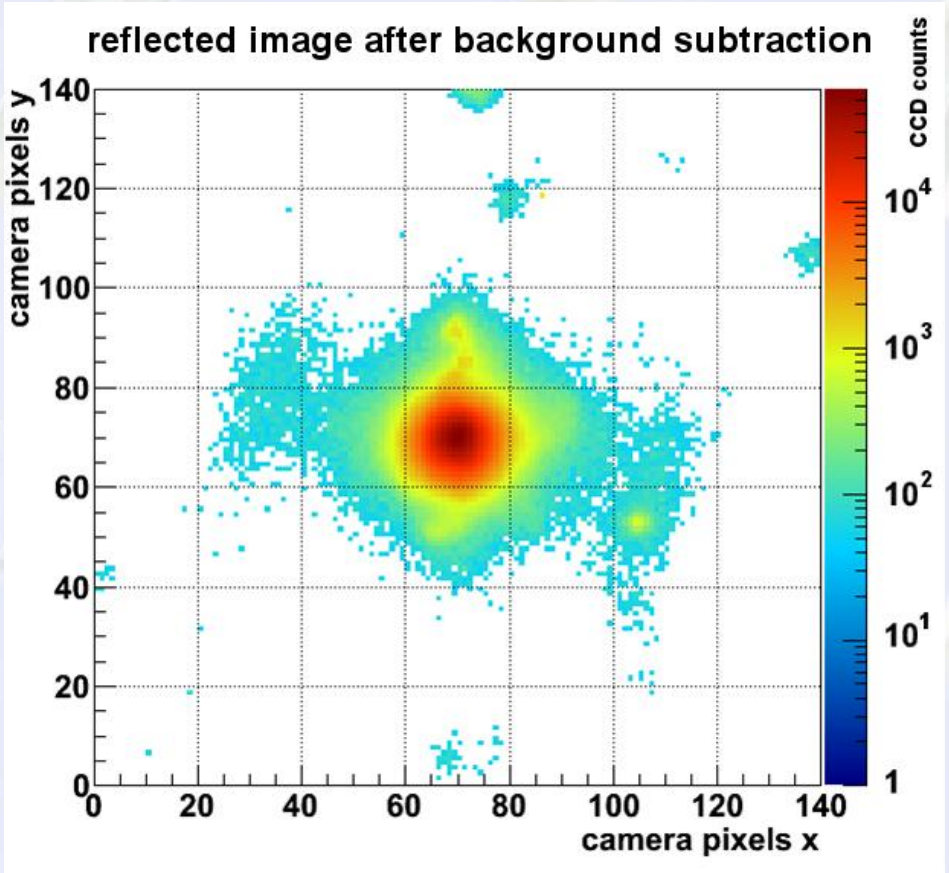


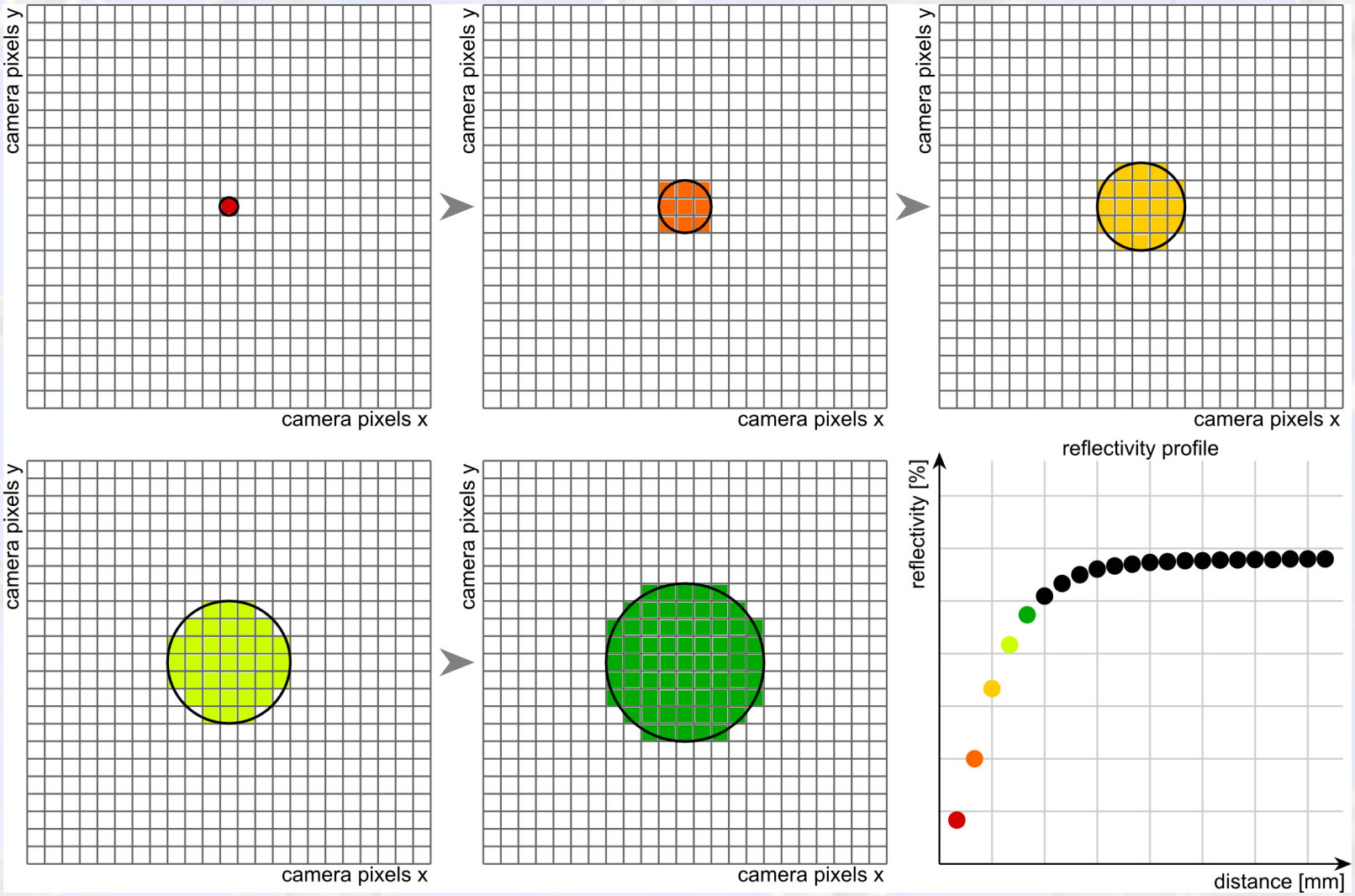
Image sections after background subtraction



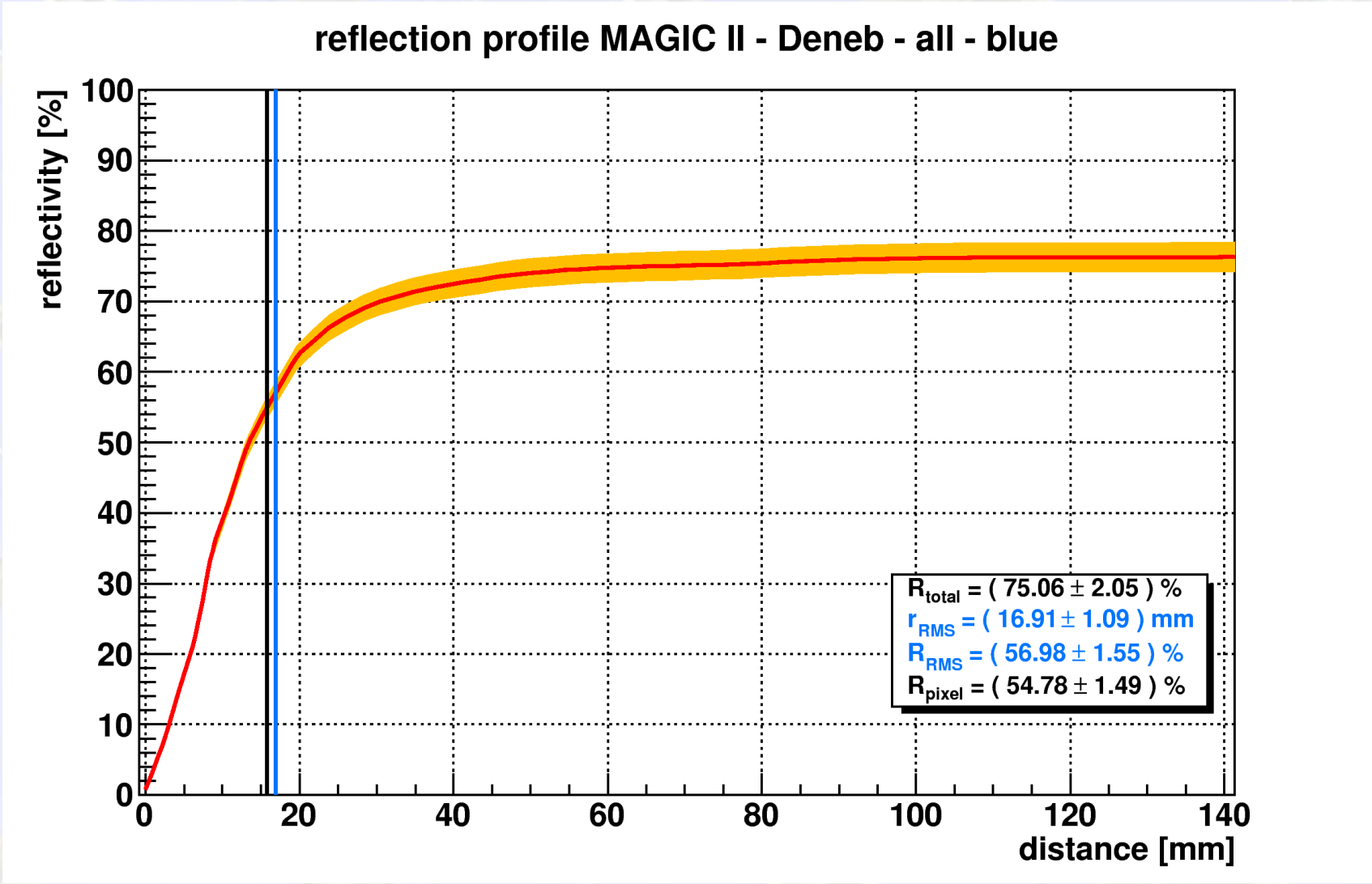
ϕ_{direkt}



Attaining the profile of the focused reflectivity



Example for a reflectivity profile



FINAL RESULTS

Telescope/Mirror	r_{RMS} [mm]	R_{RMS} [%]	R_{Pixel} [%]	R_{Total} [%]
MAGIC I	20.03±1.14	56.77±0.93	48.31±3.88	73.39±0.52
MAGIC II all	15.60±0.31	54.55±1.56	54.86±1.20	73.45±1.35
MAGIC II alu	14.06±0.58	55.46±0.95	57.47±1.25	67.47±1.00
MAGIC II glass	16.50±0.34	54.04±0.91	51.85±0.27	76.98±0.48

- The mirrors of MAGIC II have about the same reflectivity R_{Total} as those of MAGIC I.
- But the PSF of MAGIC II is better, resulting in more light going to one pixel.
- The glass mirrors of MAGIC II have a higher reflectivity R_{Total} than the alu mirrors.
- However, focusing is not as good and less light is collected.

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for more detailed information…

http://magic.mppmu.mpg.de/publications/theses/HKellermann_dipl.pdf

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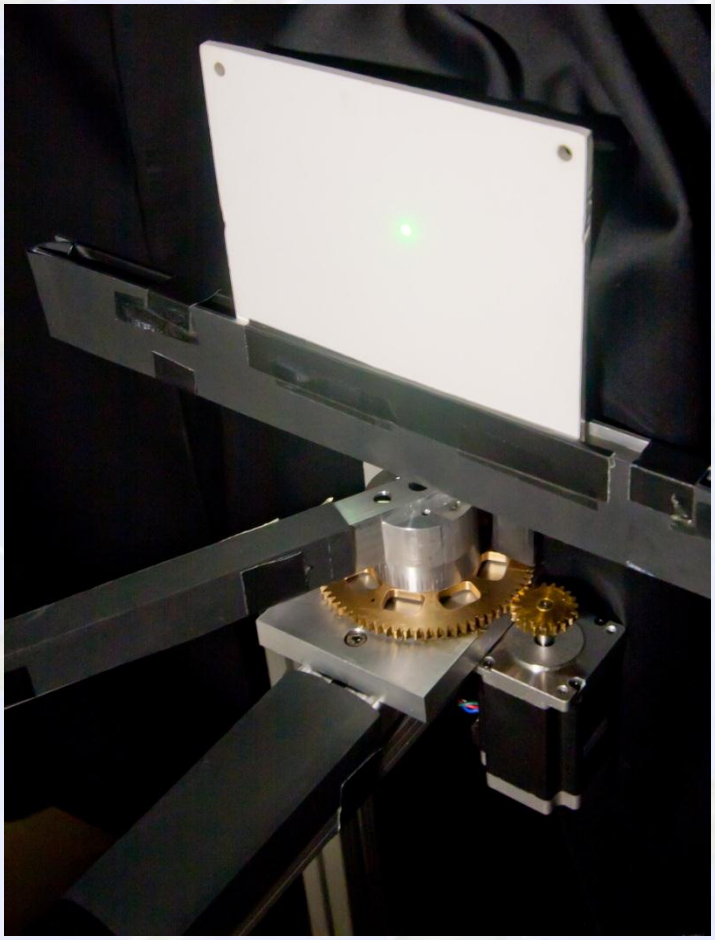
Thank you for your attention!!

Backup

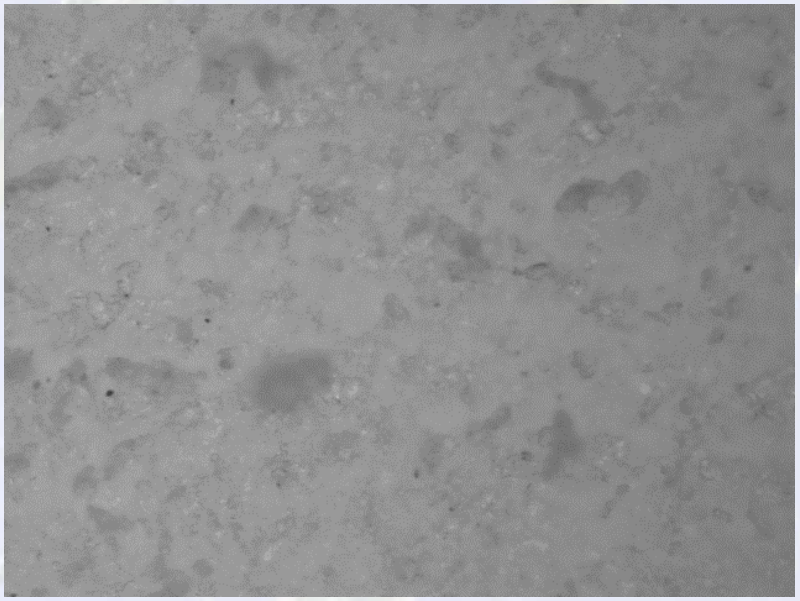
Stars used for the measurements

name	spectral type	surface tempera-ture	apparent magnitude
Polaris (α UMi)	F7	6000K - 7600K	1.97^m
Deneb (α Cyg)	A2	8400 K	1.25^m
Enif (ε Peg)	K2	3600K - 5100K	2.38^m
Fomalhaut (α PsA)	A3	8500	1.17^m
Alderamin (α Cep)	A7	7600	2.45^m
Caph (β Cas)	F2	6000K - 7600K	2.28^m
Nunki (σ Sgr)	B3	10000K - 25000K	2.00^m

Characterisatzion of the Spectralon samples

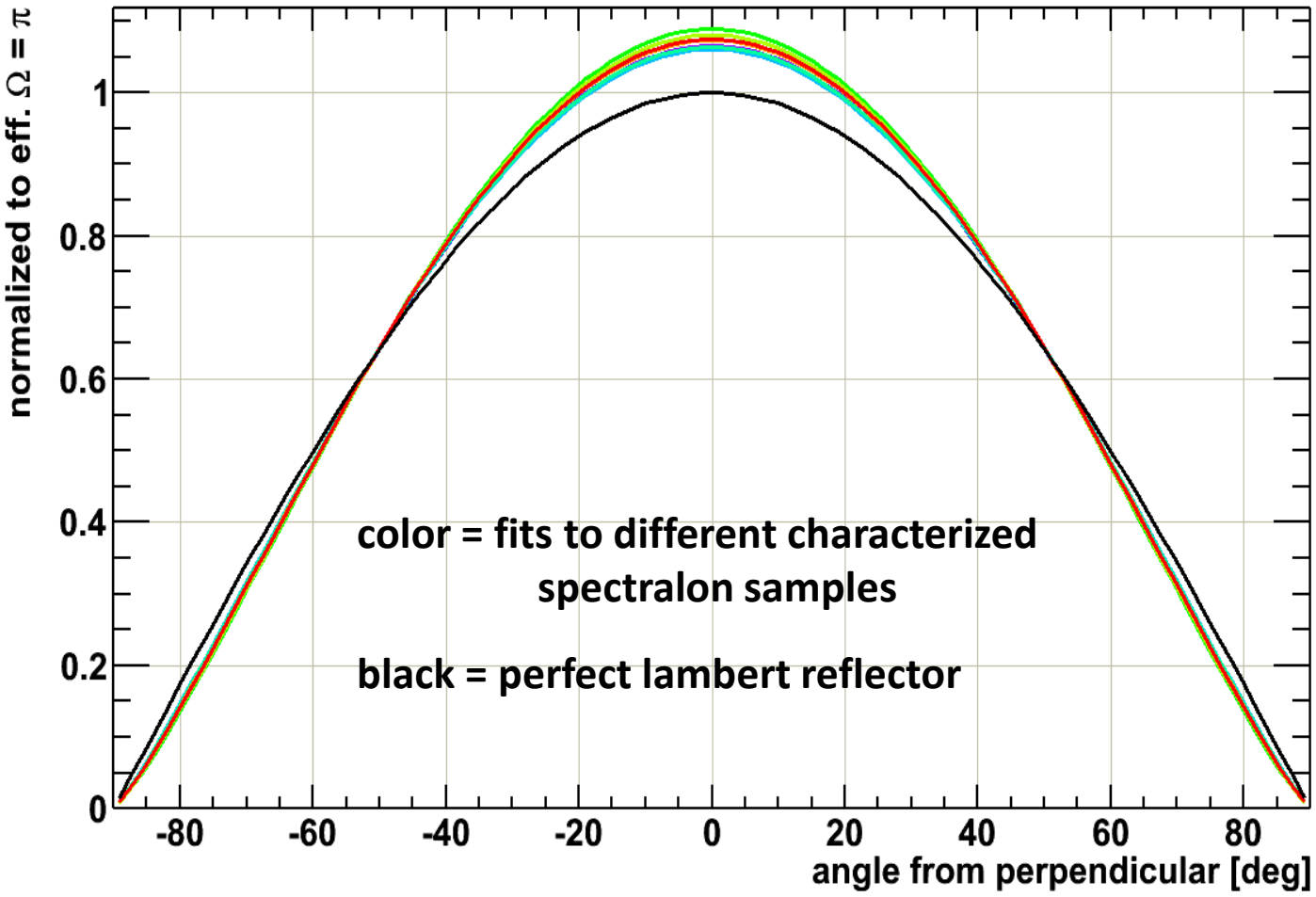


Spectralon sample in the mesurement setup

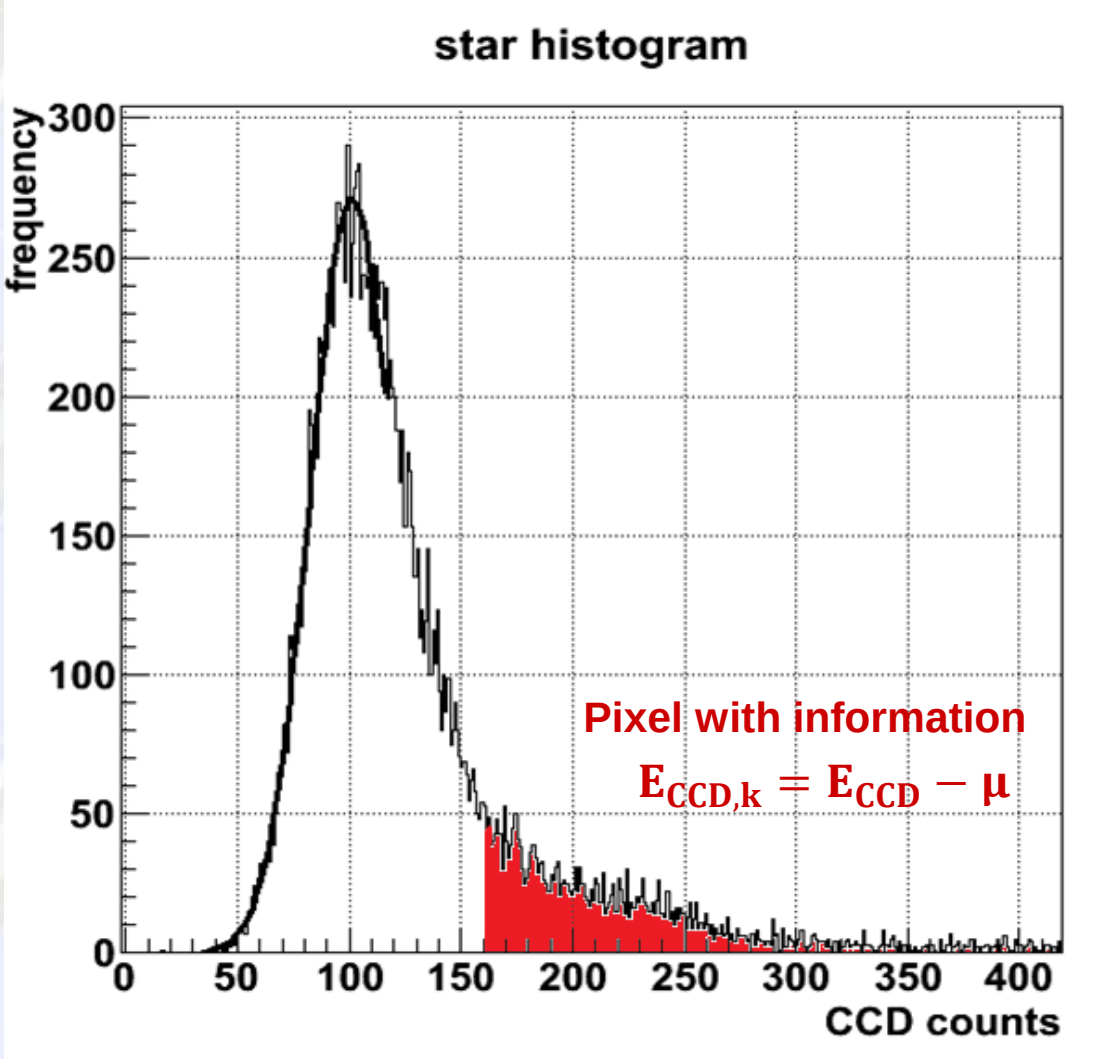


Spectralon surface under the microscope

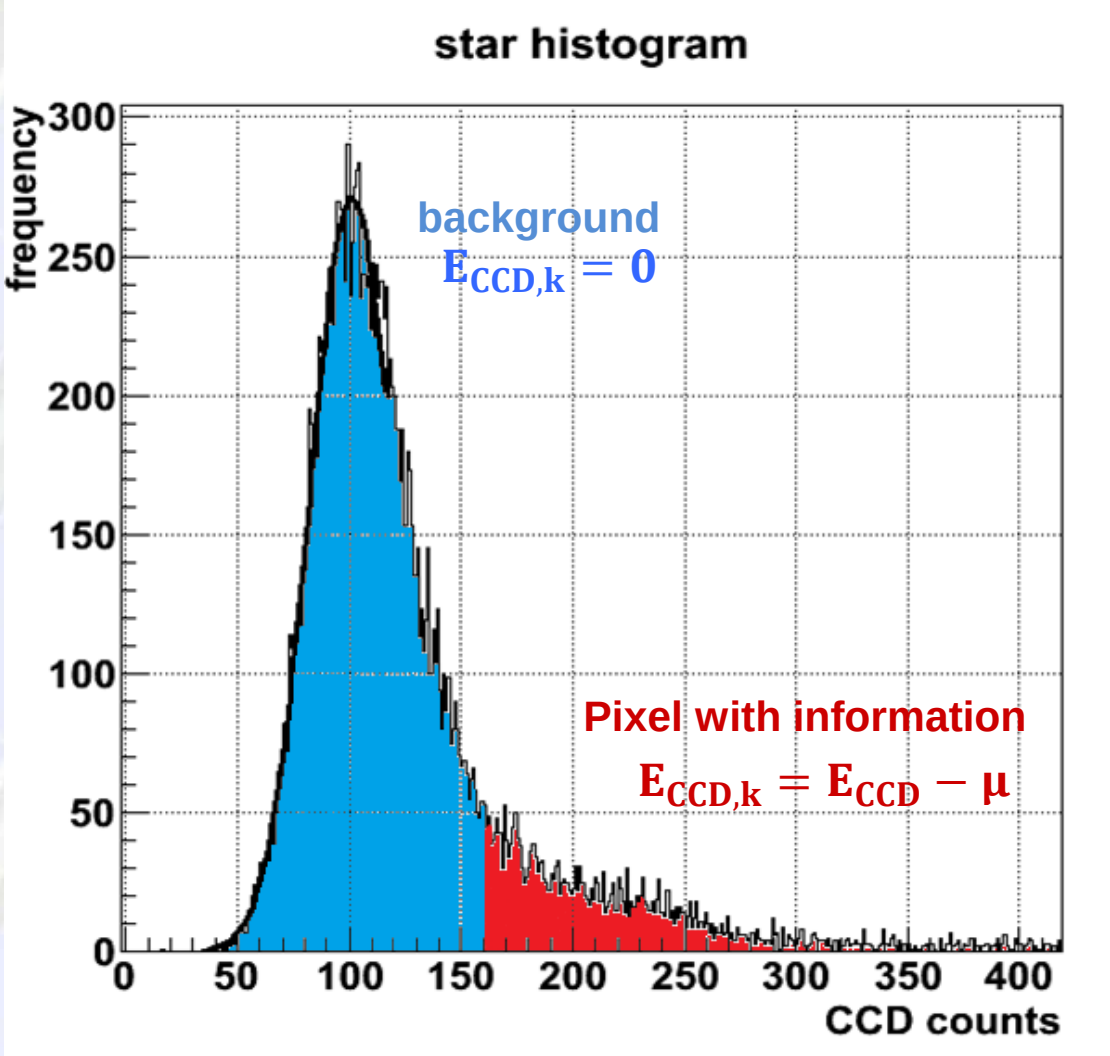
scattering characteristics of real spectralon samples vs. ideal diffuse (Lambertian) reflector



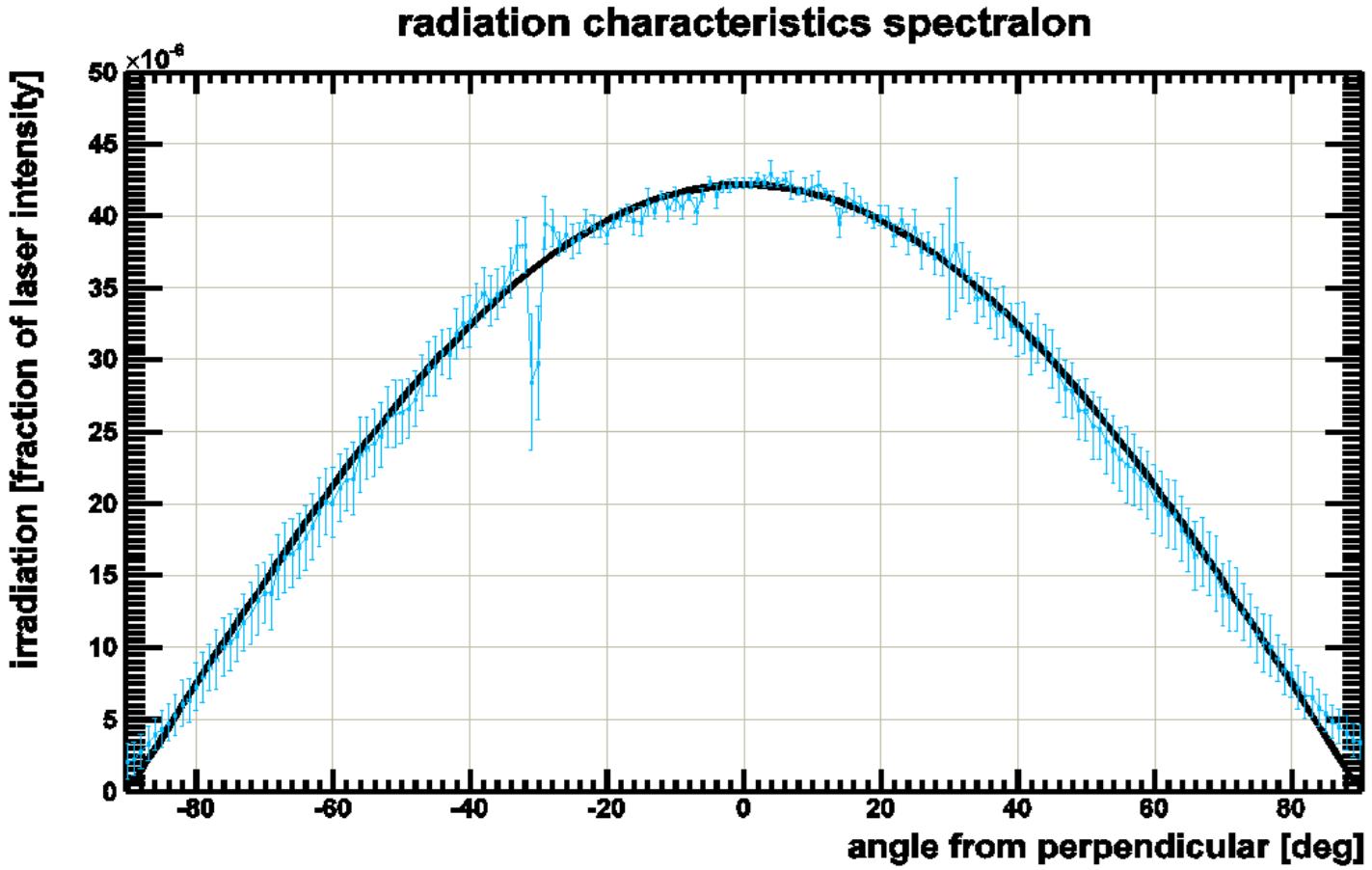
Subtracting the background



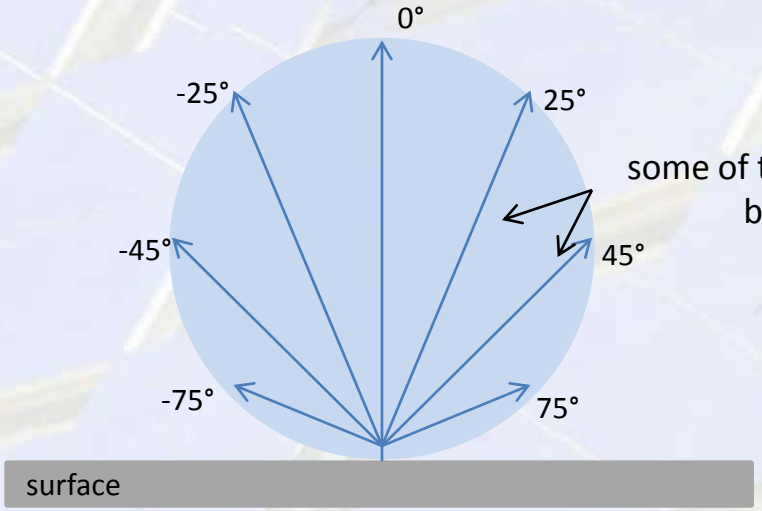
Subtracting the background



Angular scattering profile when laserpointer at 30 deg



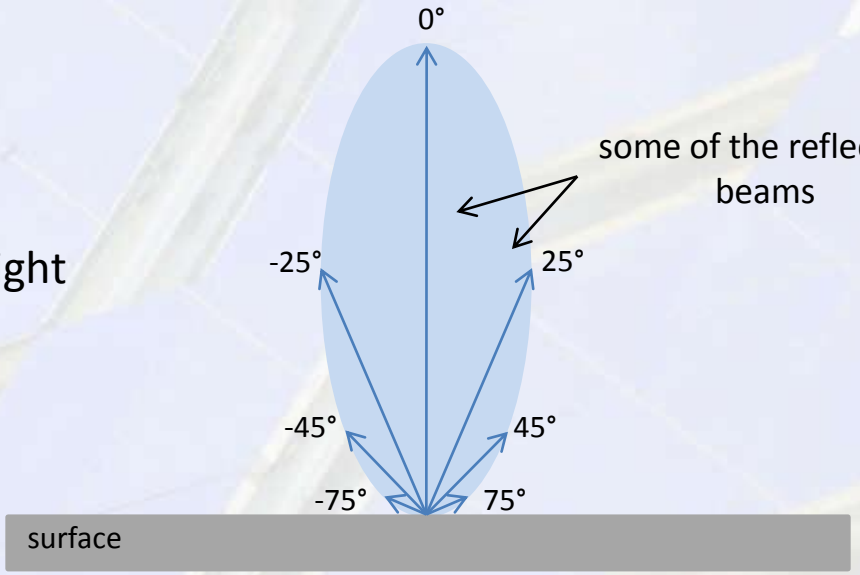
Diffuse and specular reflection



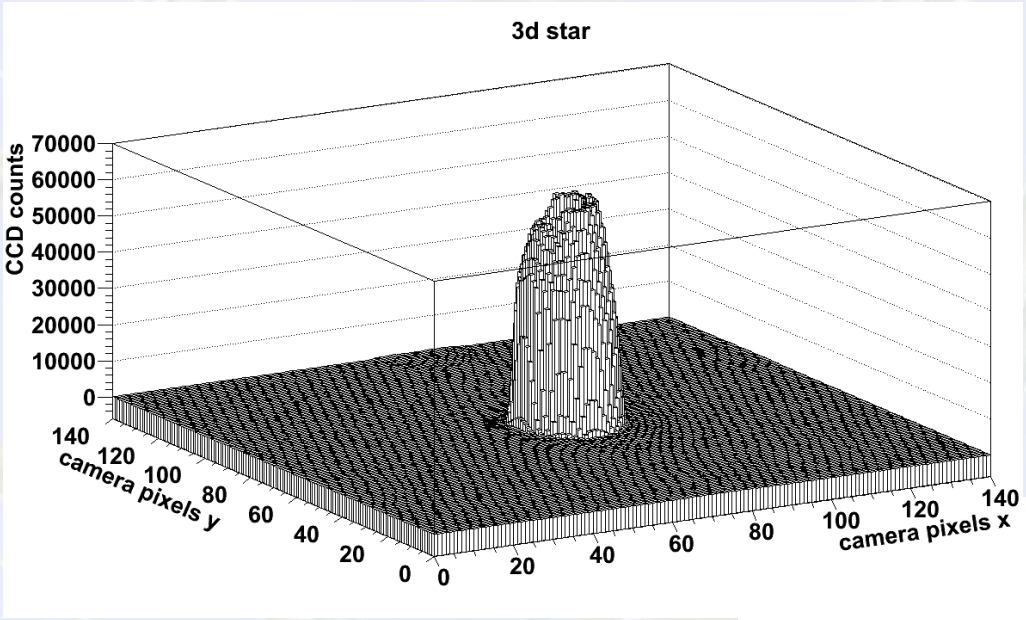
some of the reflected beams

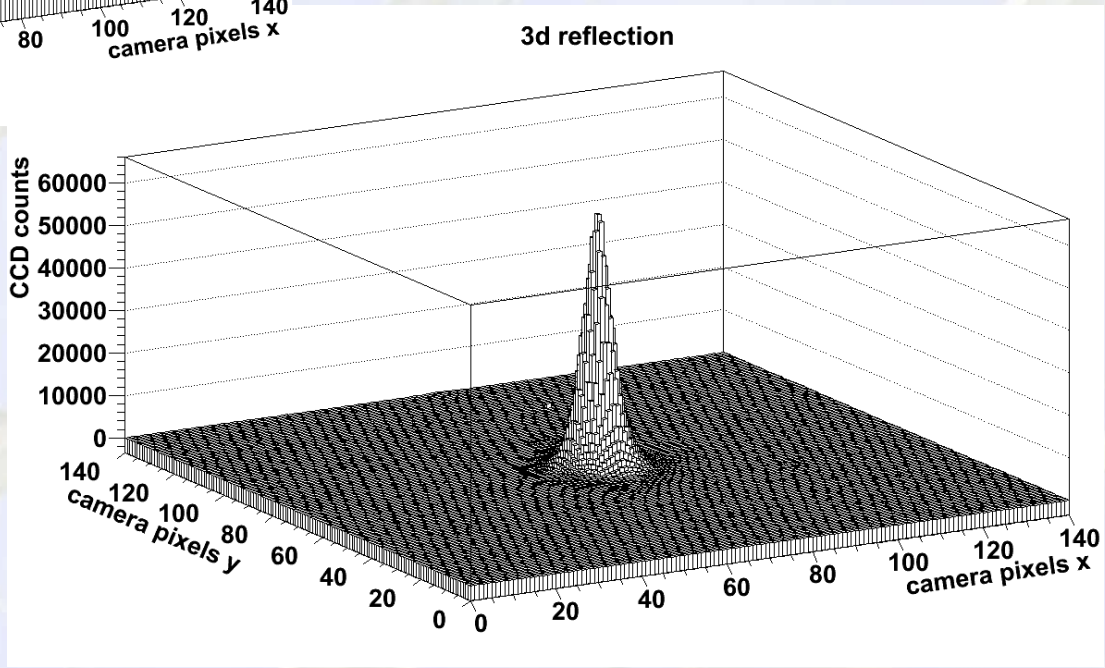
diffuse reflected light

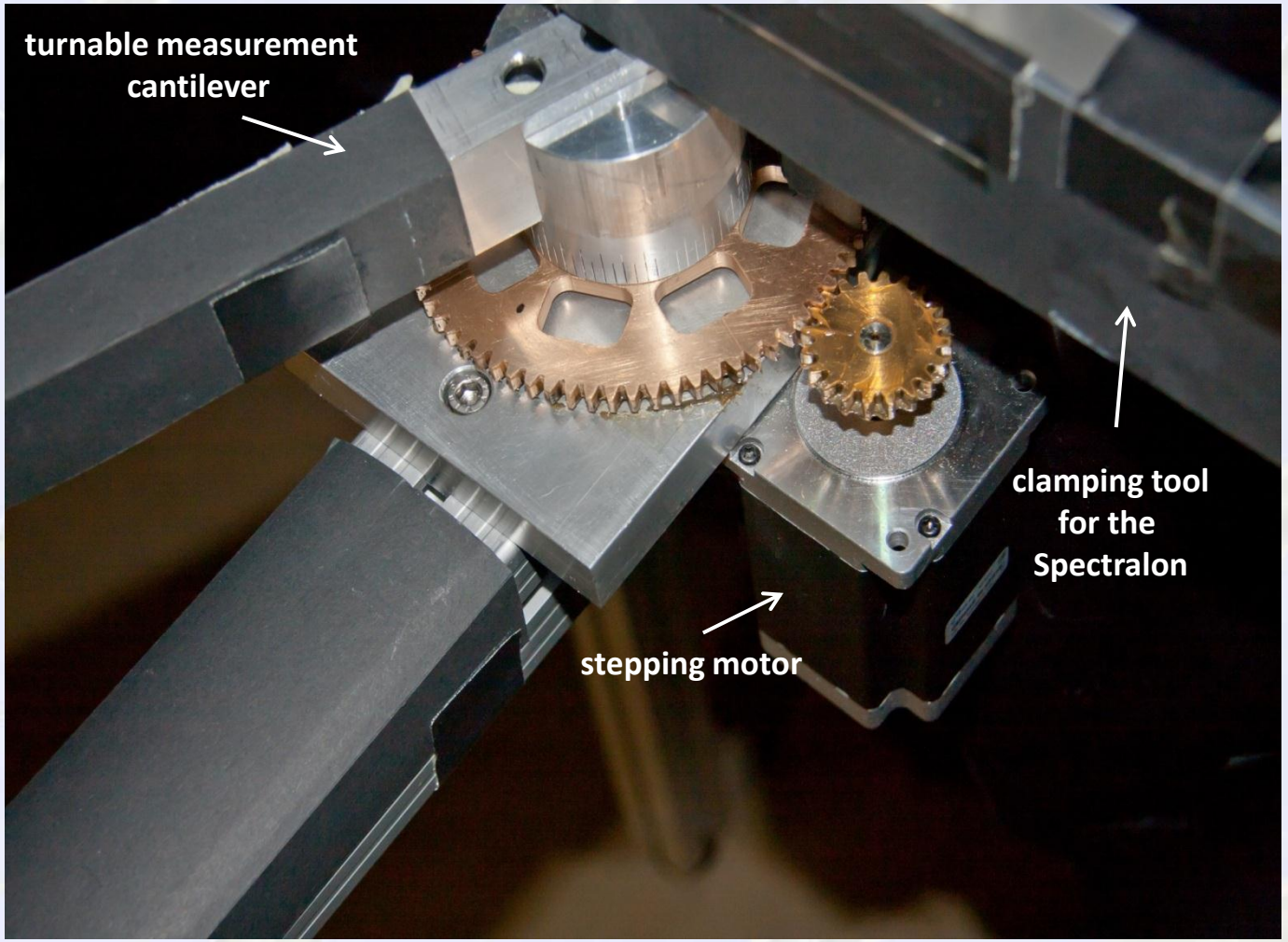
not so diffuse, more specular reflected light



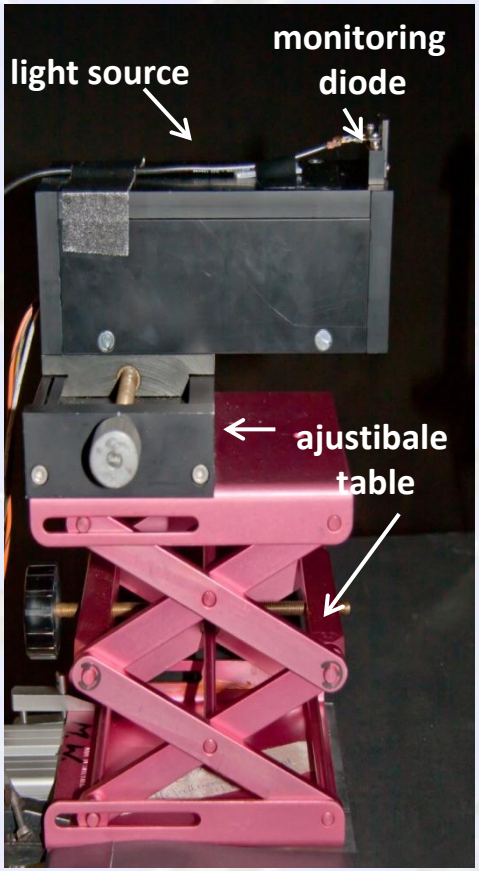
Shape of the star and the reflection

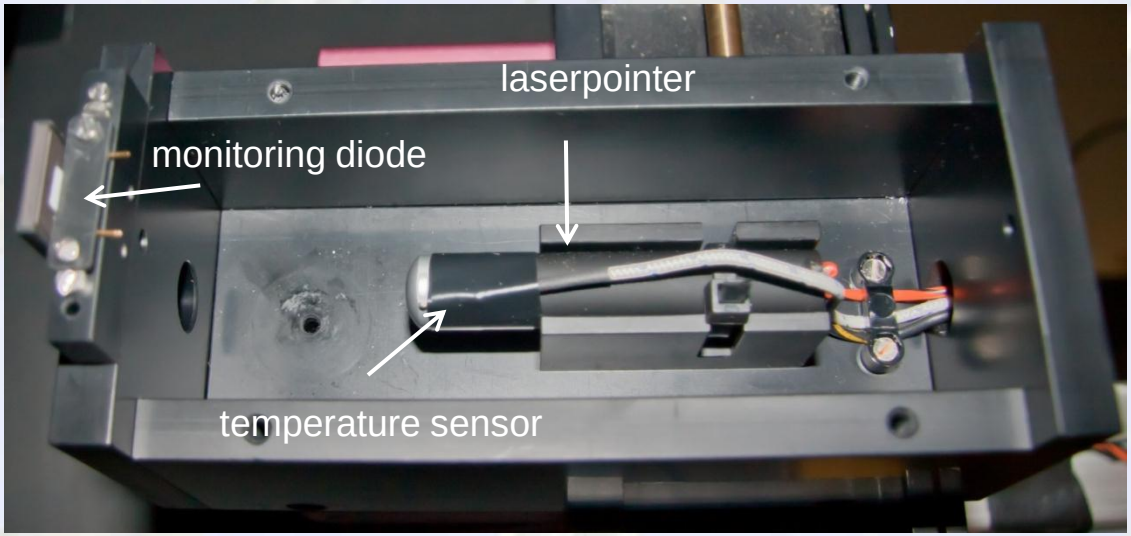




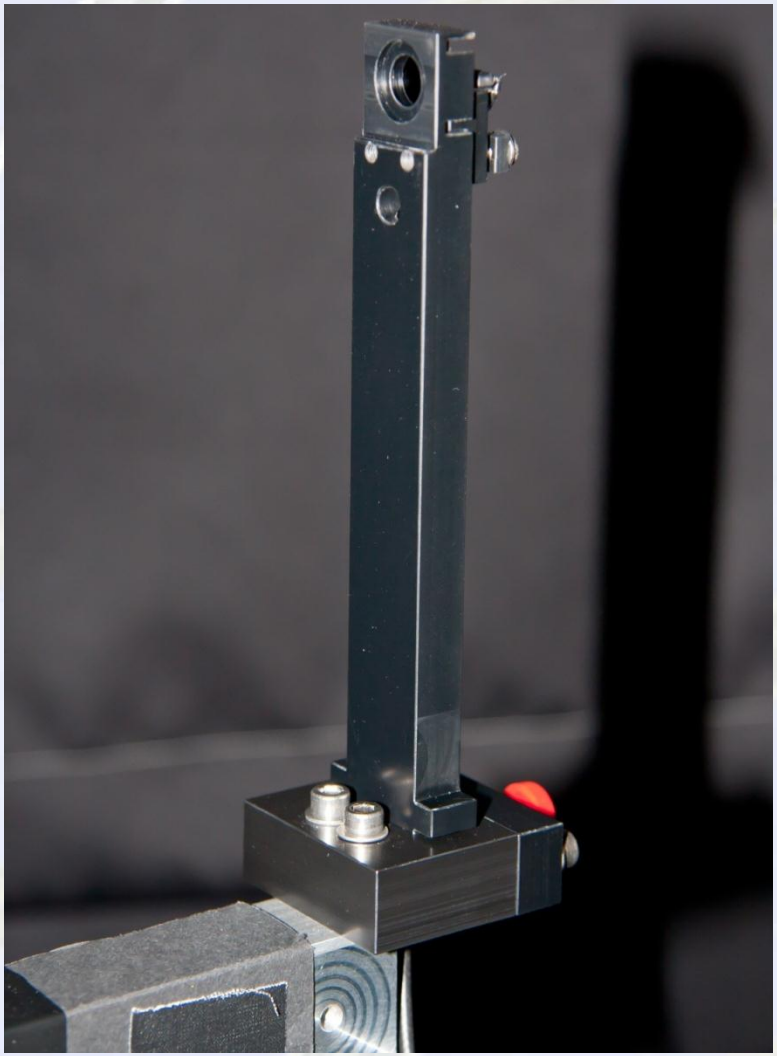

turnable measurement cantilever
clamping tool for the Spectralon
stepping motor

Light source

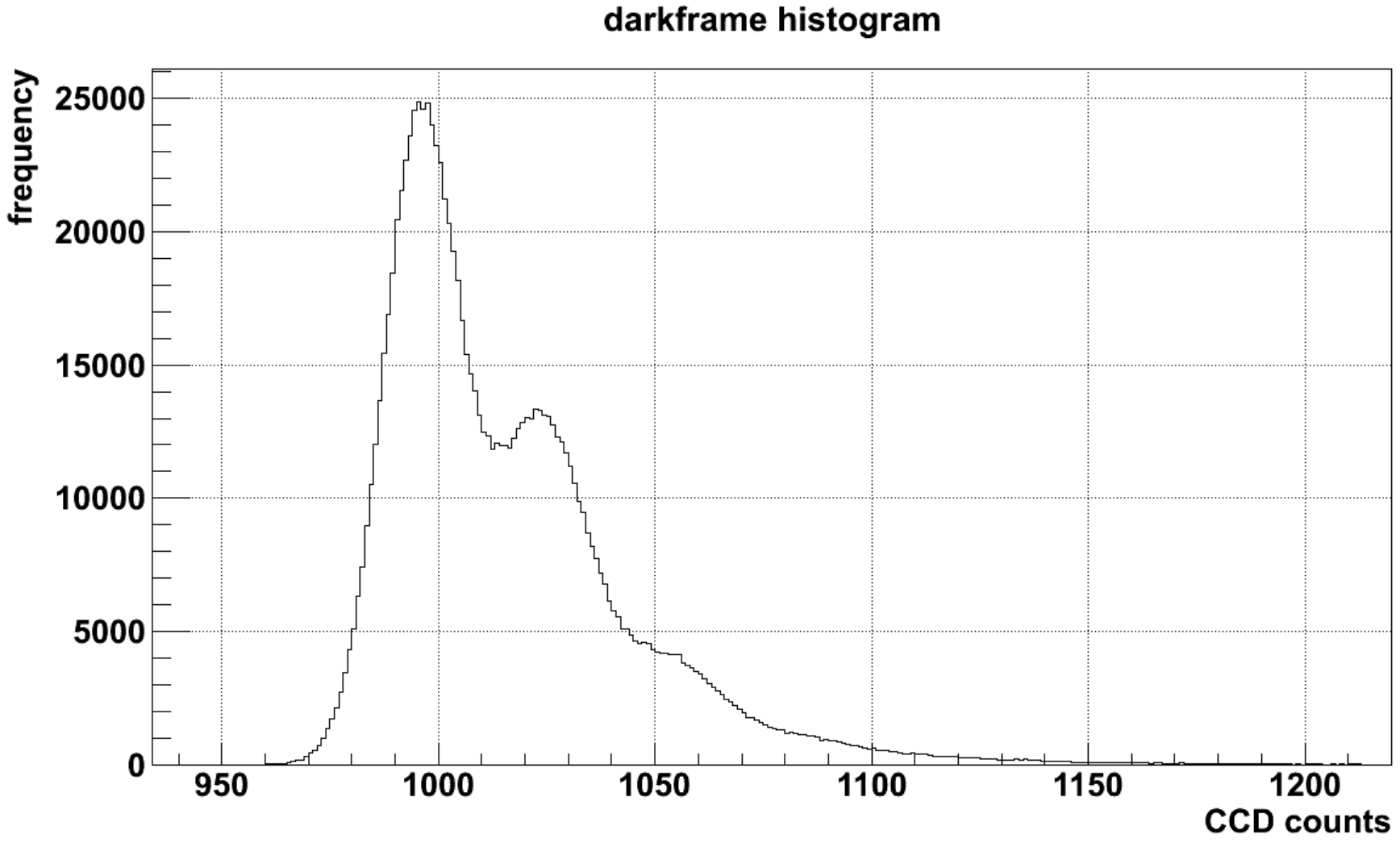


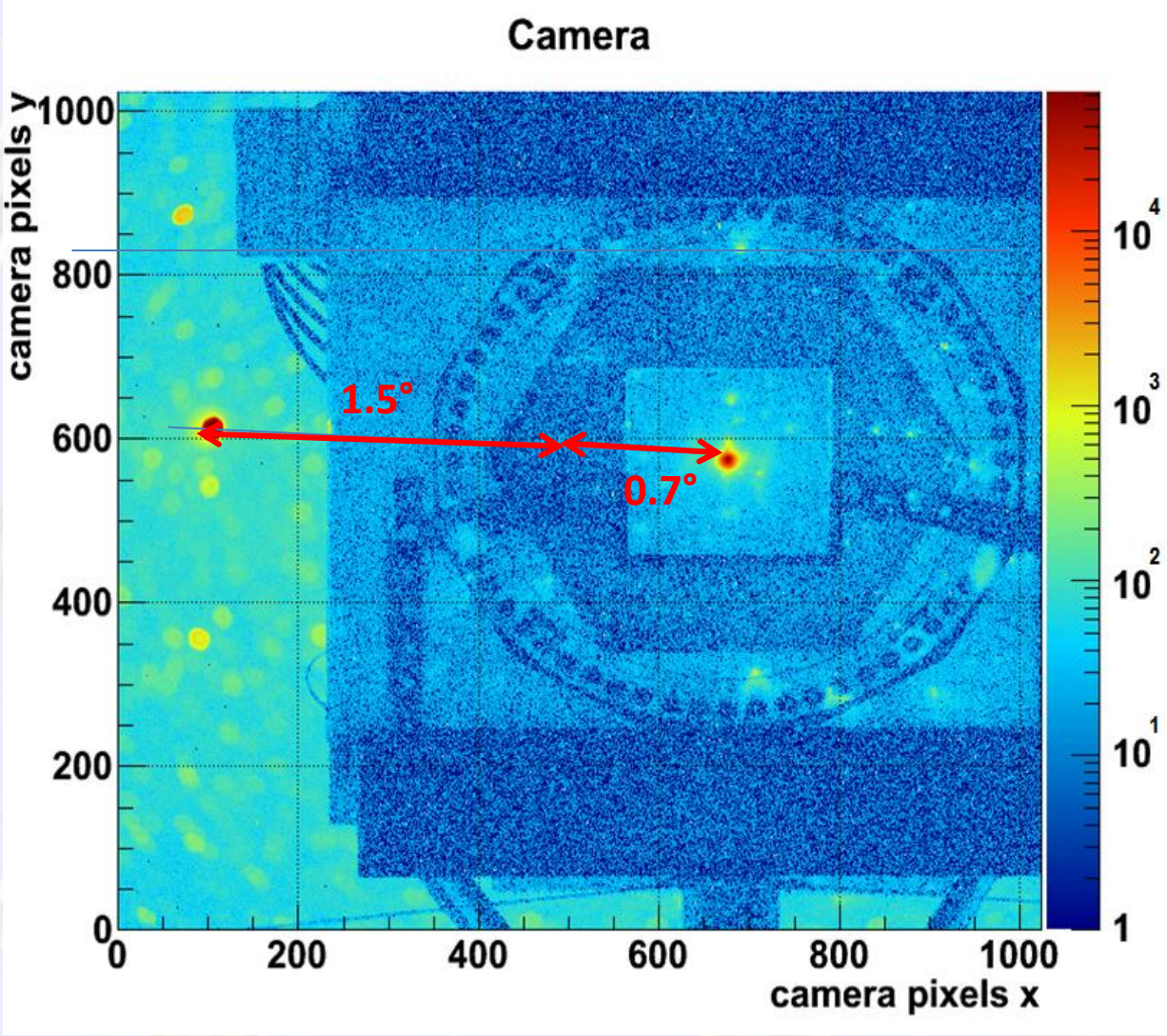


Light detector using SI Photo diode



Strange behavior of the CCD chip




Camera
camera pixels y
1000
800
600
400
200
0
0
200
400
600
800
1000
camera pixels x
1.5°
0.7°
10^4
10^3
10^2
10^1
1